

REPORT DOCUMENTATION PAGE

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30

MEMORANDUM FOR IN-HOUSE PUBLICATIONS

FROM: PROI (TI) (STINFO)

10 Jul 98

SUBJECT: Authorization for Release of Technical Information, Control Number: AFRL-PR-ED-TP-1998-160
Dr. Quinn "AFRL Propulsion Directorate Briefing for Industry (Space Propulsion Thrust)"
NAECON Briefing (Statement A)

20020823 043

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:

a. REPORT

Unclassified

b. ABSTRACT

Unclassified

c. THIS PAGE

Unclassified

17. LIMITATION OF ABSTRACT

A

18. NUMBER OF PAGES

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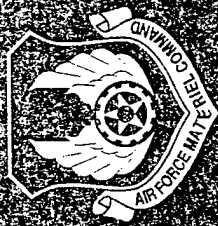
Leilani Richardson

19b. TELEPHONE NUMBER

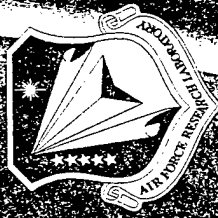
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Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std. Z39.18

41 items enclosed



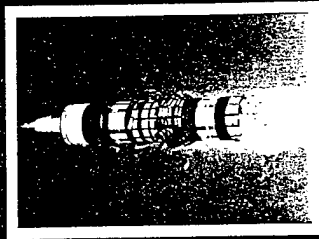
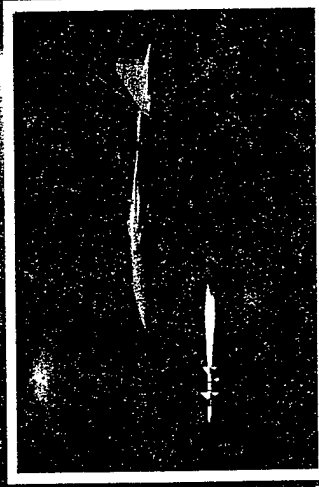
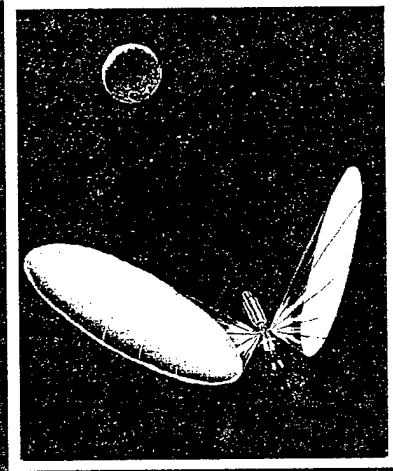
Air Force Research Laboratory



Propulsion Directorate

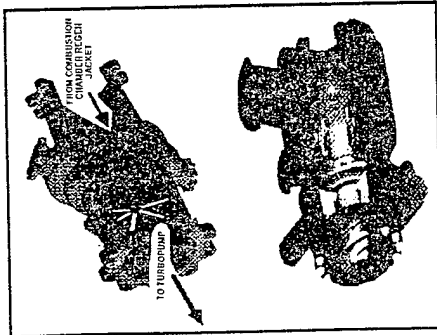
Rocket Propulsion Division

Dr. Lawrence P. Quinn

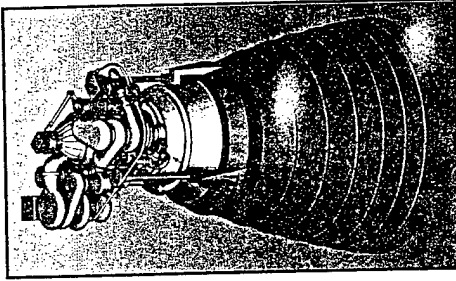




Air Force Research Laboratory Rocket Propulsion Division

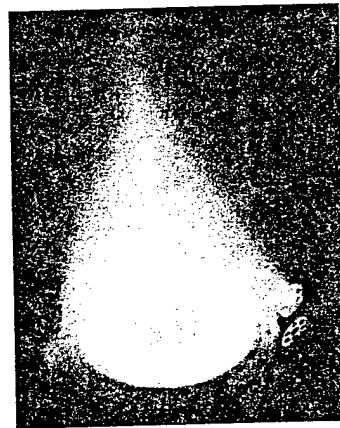


INTEGRATED POWERHEAD
DEMONSTRATION



ADVANCED EXPANDER
CYCLE ENGINE

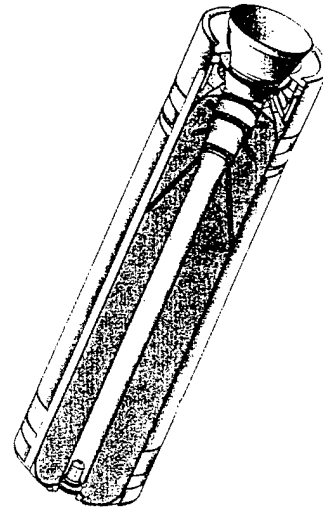
Mission Statement
**Create Rocket Propulsion
Technologies for the
Warfighter to Control and
Exploit Space & Air**



HALL THRUSTER



HYBRID BOOST



SUSTAINMENT MOTOR

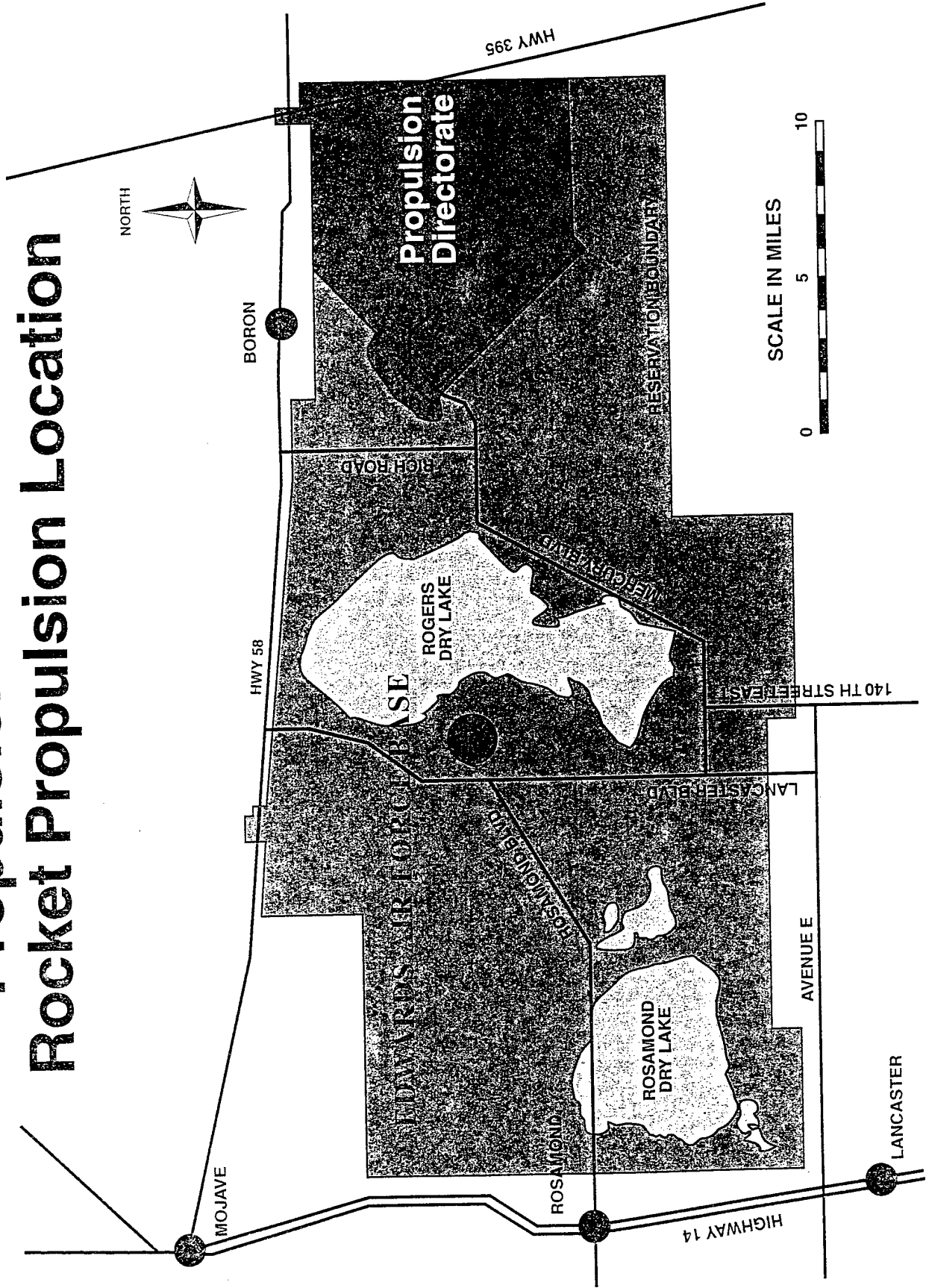


Outline



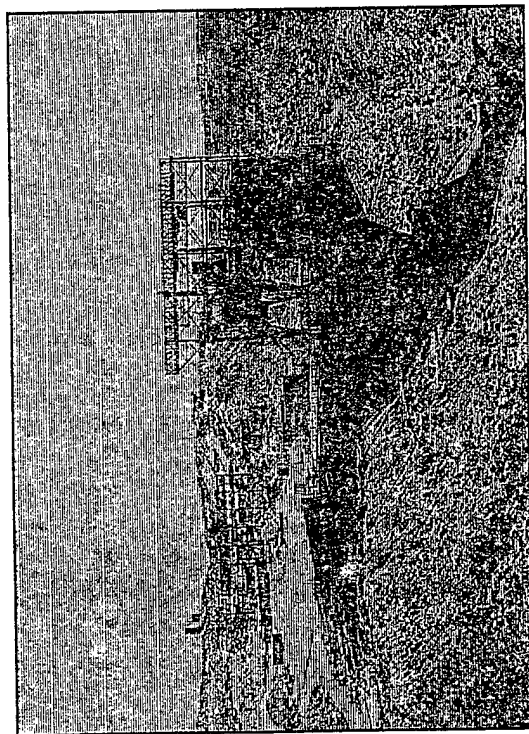
- Who Are We?
- What Have We Done?
- Integrated High Payoff Rocket Propulsion Technology
- What Are We Doing?

Propulsion Directorate Rocket Propulsion Location

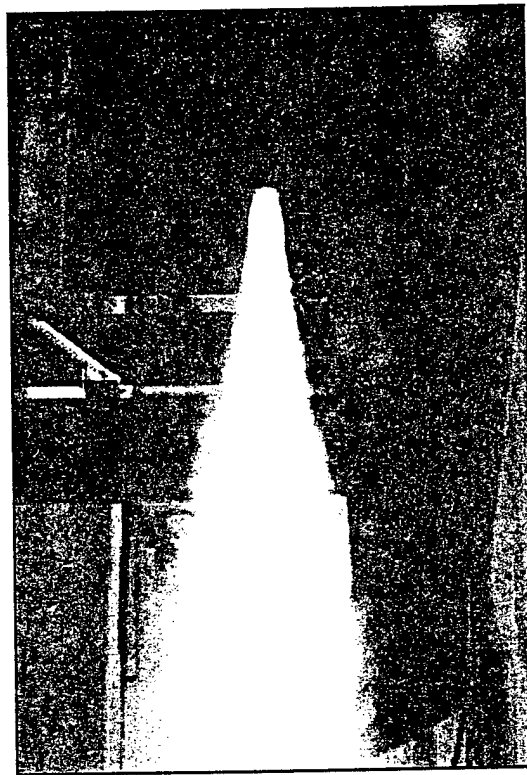




Facilities



**NINETEEN LIQUID ENGINE
STANDS TO 8,000,000 LBS THRUST**



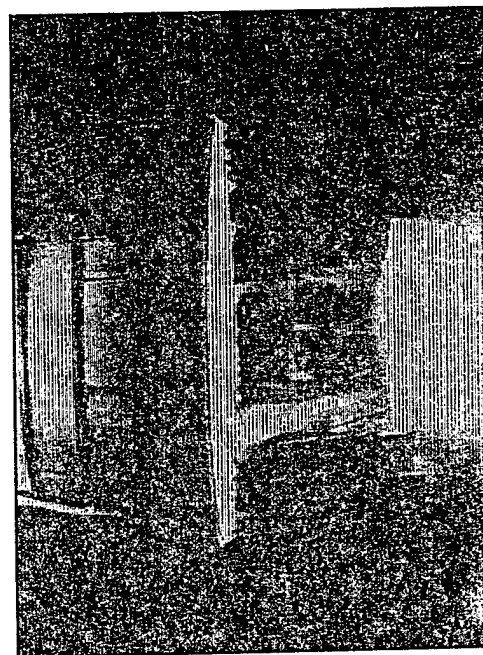
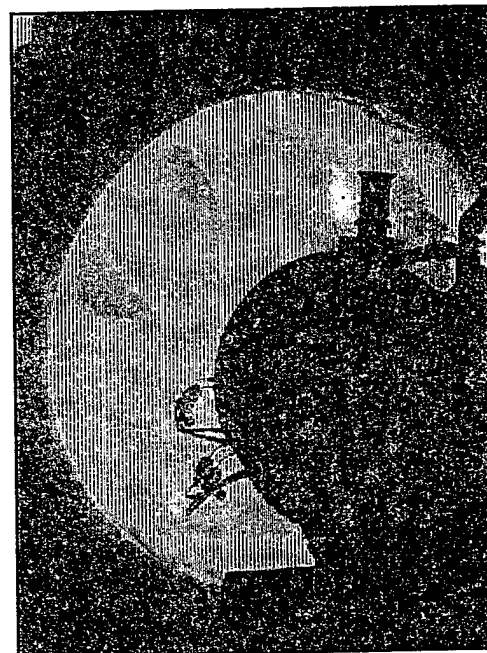
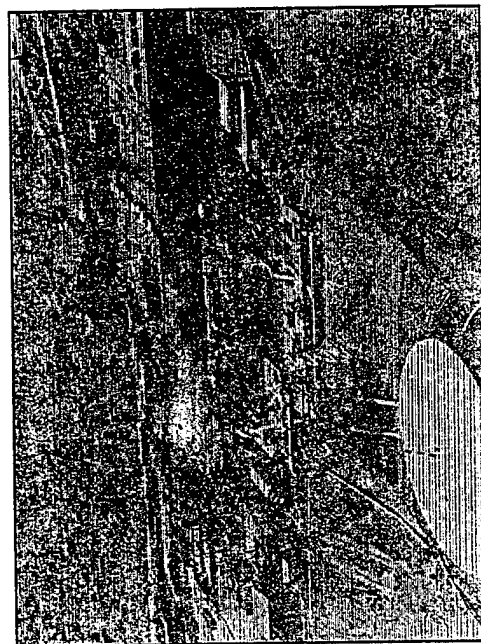
**THIRTEEN SOLID ROCKET MOTOR
PADS TO 10,000,000 LBS THRUST**





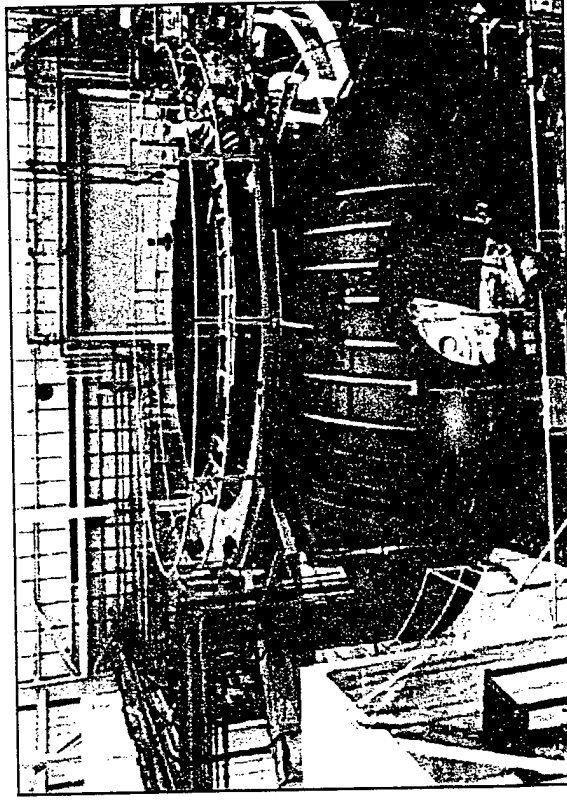
Altitude Facilities

FROM MILLIPOUNDS TO 60,000 LBS THRUST





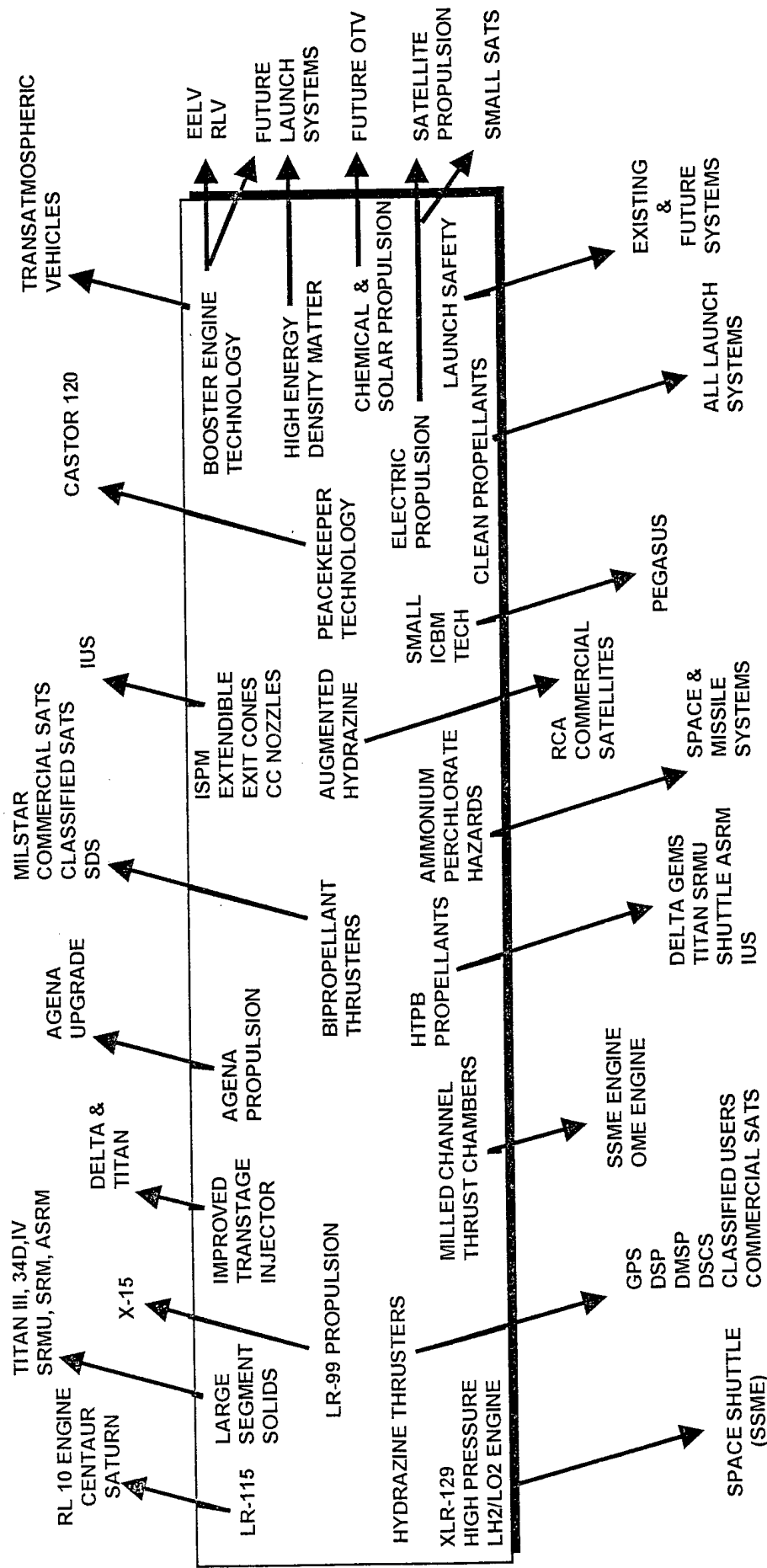
Combined Space Environment Simulation



30 FT DIAMETER LIQUID NITROGEN
COLD WALL QUARTZ LAMP SOLAR SIMULATION

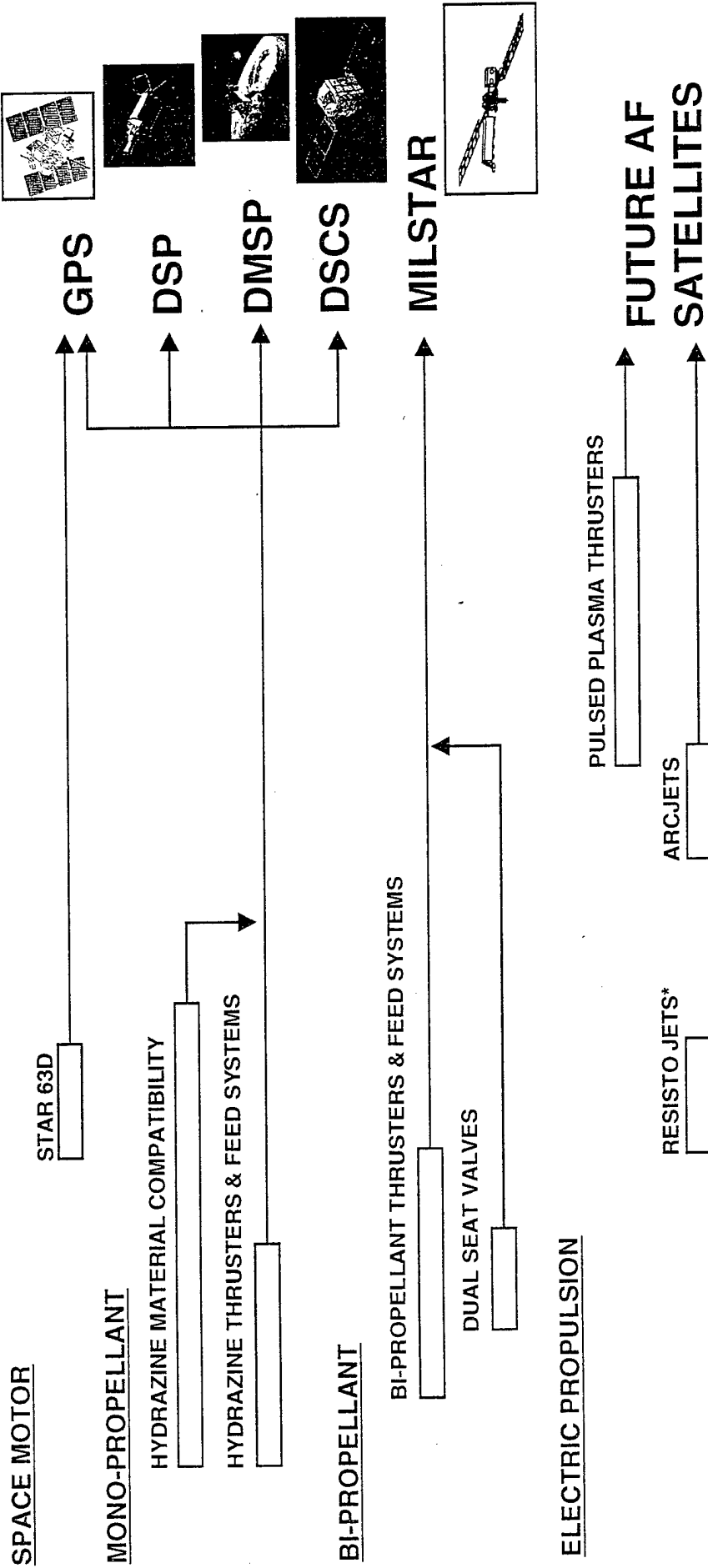


Air Force Research Laboratory Space Propulsion Contributions



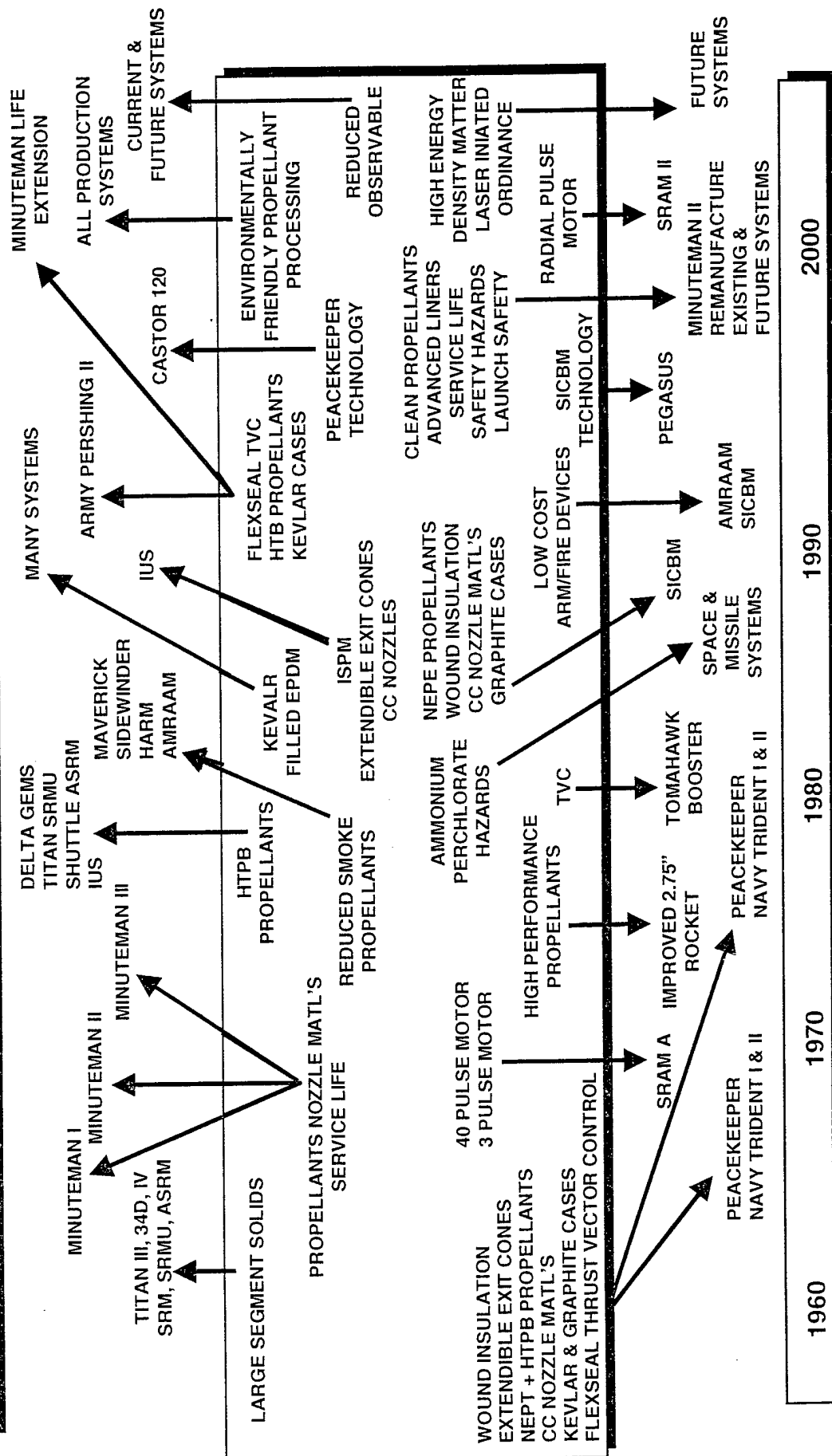


Air Force Research Laboratory Contribution to Air Force Satellite Propulsion



1960 1970 1980 1990 2000 2005

* \$1M AFRL Investment Extended On-Orbit Life and Generated Over \$1B Additional Income on Lockheed-Martin Commercial Satellites.





Air Force Research Laboratory Contribution to Peacekeeper ICBM



PROPELLANT

- * + HTPB(HYDROXY TERMINATED POLYBUTADIENE)
- NEPE(NITRATE ESTER POLYETHER)

NOZZLE

- + CARBON-CARBON INTEGRAL THROAT INSERT
- * + FLEXSEAL TVC
- + EXPANDABLE EXIT CONES

MOTOR CASE

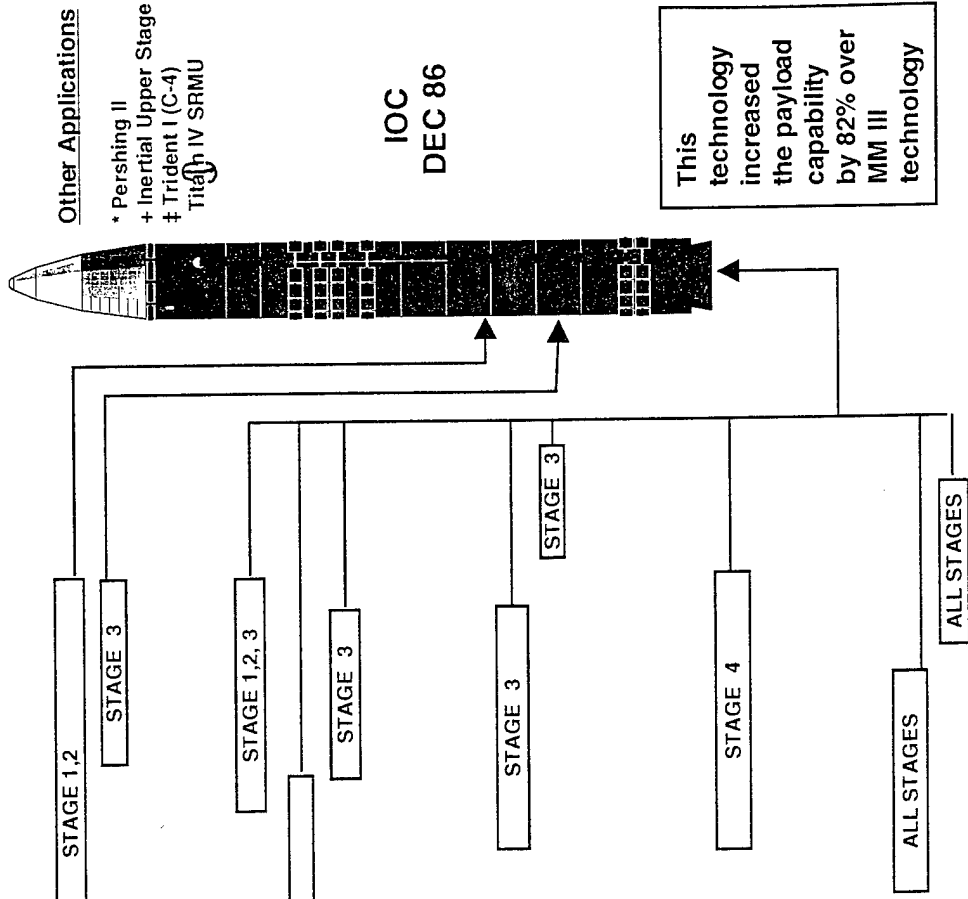
- LOW LENGTH-TO-DIAMETER KEVLAR
- WOUND ELASTOMERIC INSULATION

PBPS

- INJECTED MOLDED ATTITUDE
- CONTROL ENGINE THRUST CHAMBER

OTHER

- NUCLEAR EFFECTS STUDIES
- ORDNANCE TEST SUPPORT



1960

1970

1980



Propulsion Related AFSPC Deficiencies

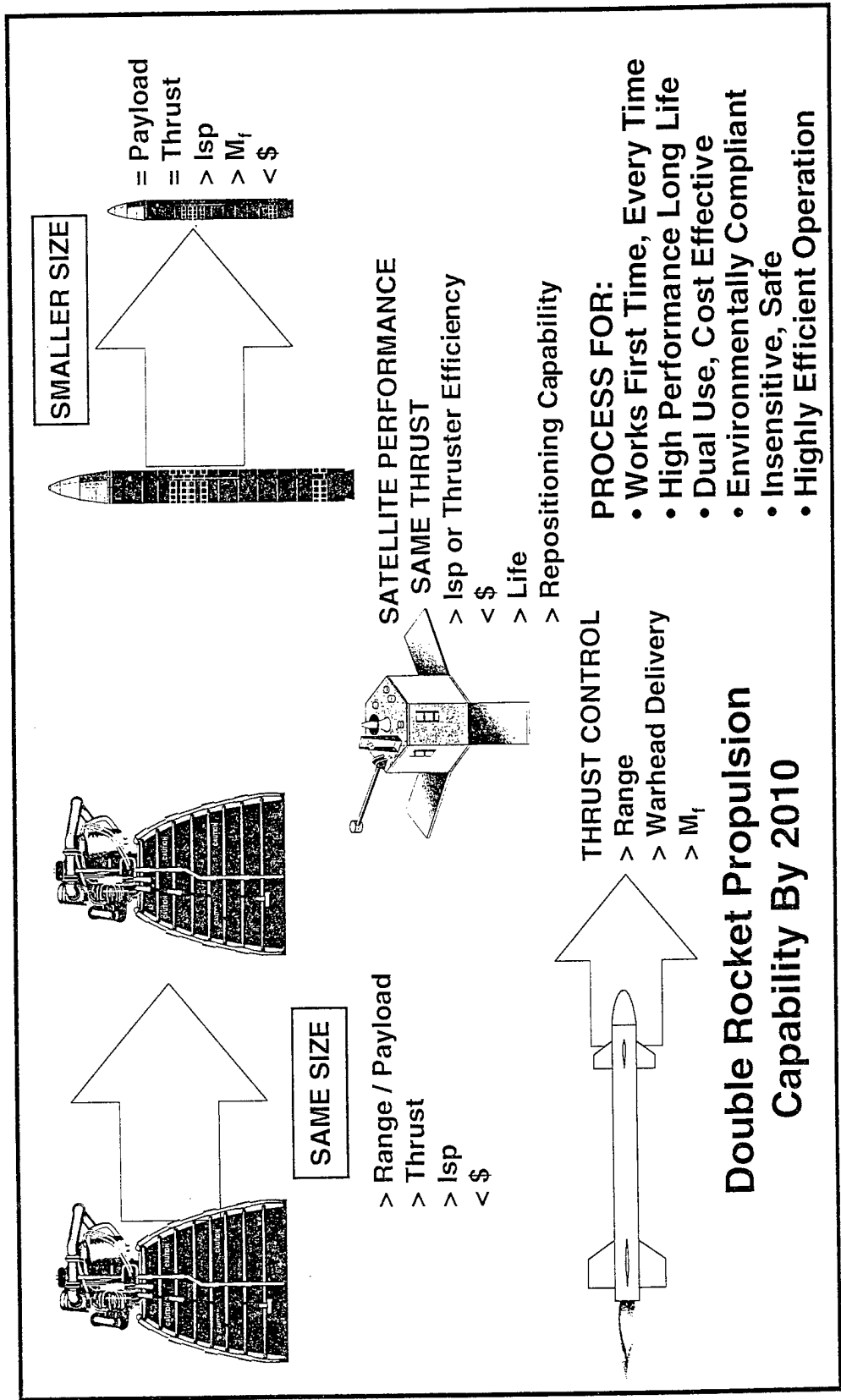
A0168...



- **Costly Spacelift**
- **Unresponsive Spacelift**
- **Satellite Repositioning**
- **Satellite Recovery & On-Orbit Service**
- **Global Mobility Via Space**
- **Lack of DoD Space System Protection Capability**



IHPRPT is...

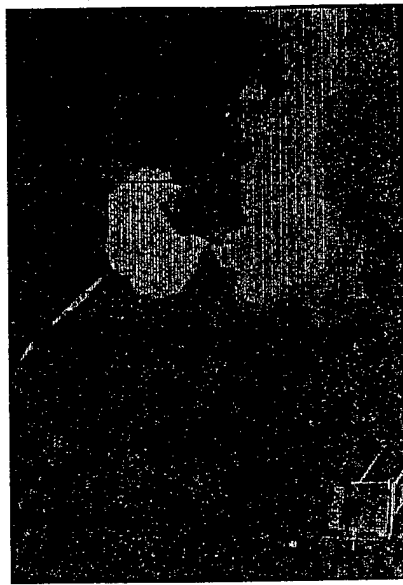
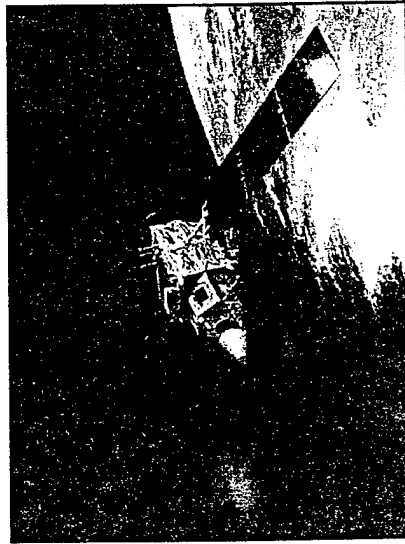
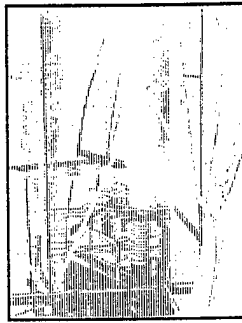
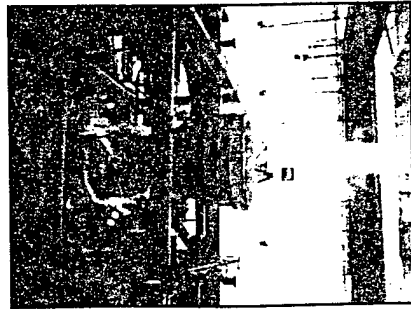




IHPRPT Investment Impacts

**Propulsion Performance has Major Impacts on
Vehicle Size/Weight**

**Propulsion Represents the Limiting Factor in Future
Military and Commercial Capabilities**



PROPULSION IS...

Boost

70-90% Takeoff System Weight
40-60% System Cost

Spacecraft

Life Limiting Factor
25-40% System Cost
50-70% Satellite Weight

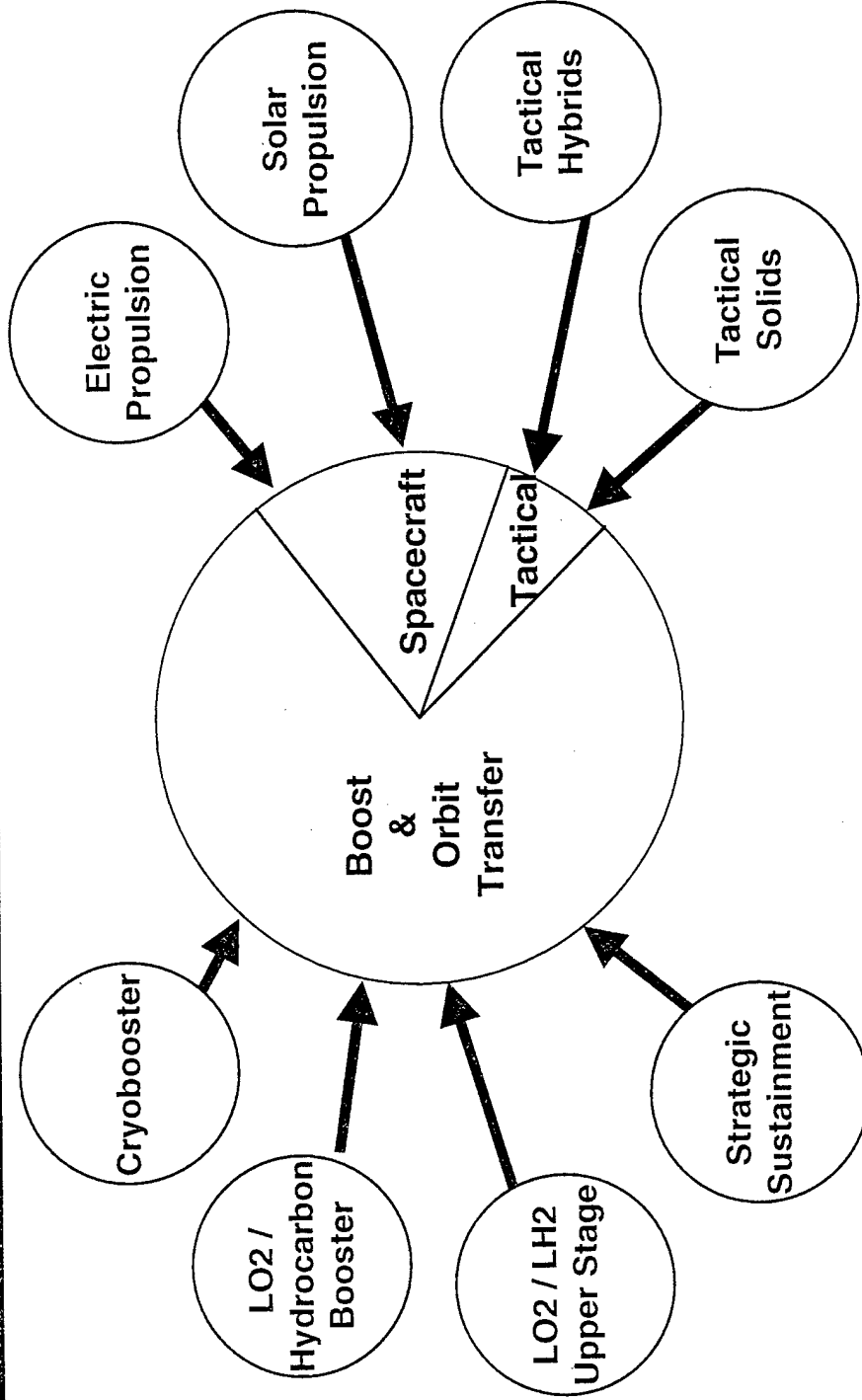
Tactical

60-80% Missile Weight
Critical Factor in Decreasing
Time-to-Target



Propulsion Directorate

Primary IHPRT Focus Areas



Advanced Concepts

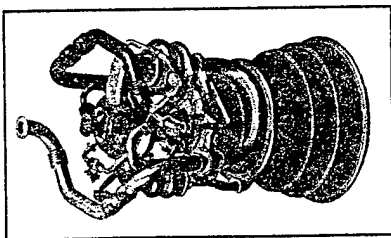
Advanced Propellants

Materials Applications

Aerophysics

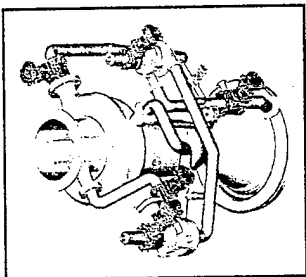


Rocket Propulsion Division Key Programs



Integrated Powerhead Demo

- Develop Enabling Technologies for Advanced Cryogenic Engines
- Enables Reusable Space Launch Vehicles



Advanced Expander Cycle Upper Stage Engine

- Develop Technologies for the Next Generation Upper Stage Engines
- Increased Reliability, Increased Payload, Decreased Cost



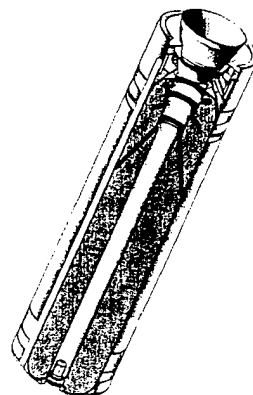
Hybrid Propulsion

- Develop Hybrid Propulsion for Tactical, Upper Stages and Boost Systems
- Increased Operational Effectiveness, Inherent Safety and Increased Performance



Electric Propulsion

- Develop Advanced Spacecraft Propulsion
- Improved Orbit Transfer, Stationkeeping and Repositioning of Satellites



Strategic Sustainment

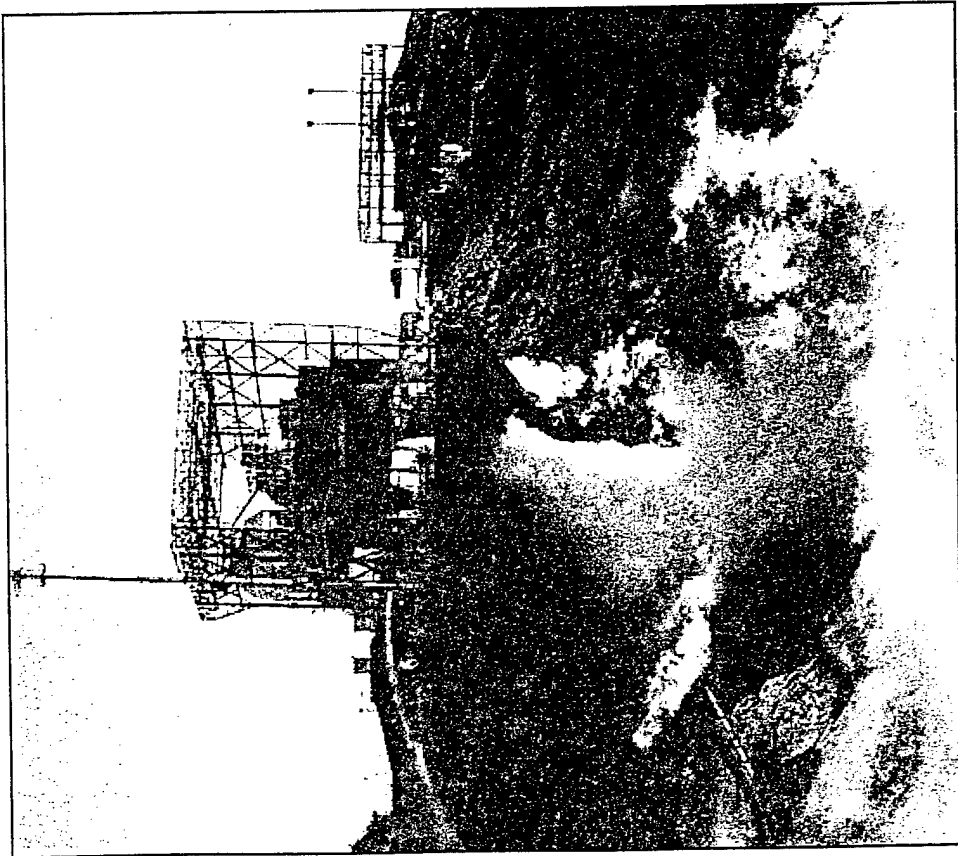
- Technology Efforts for Sustainment of Strategic Systems
- Sustainment of Existing Systems and Industrial Capacity



EELV Support



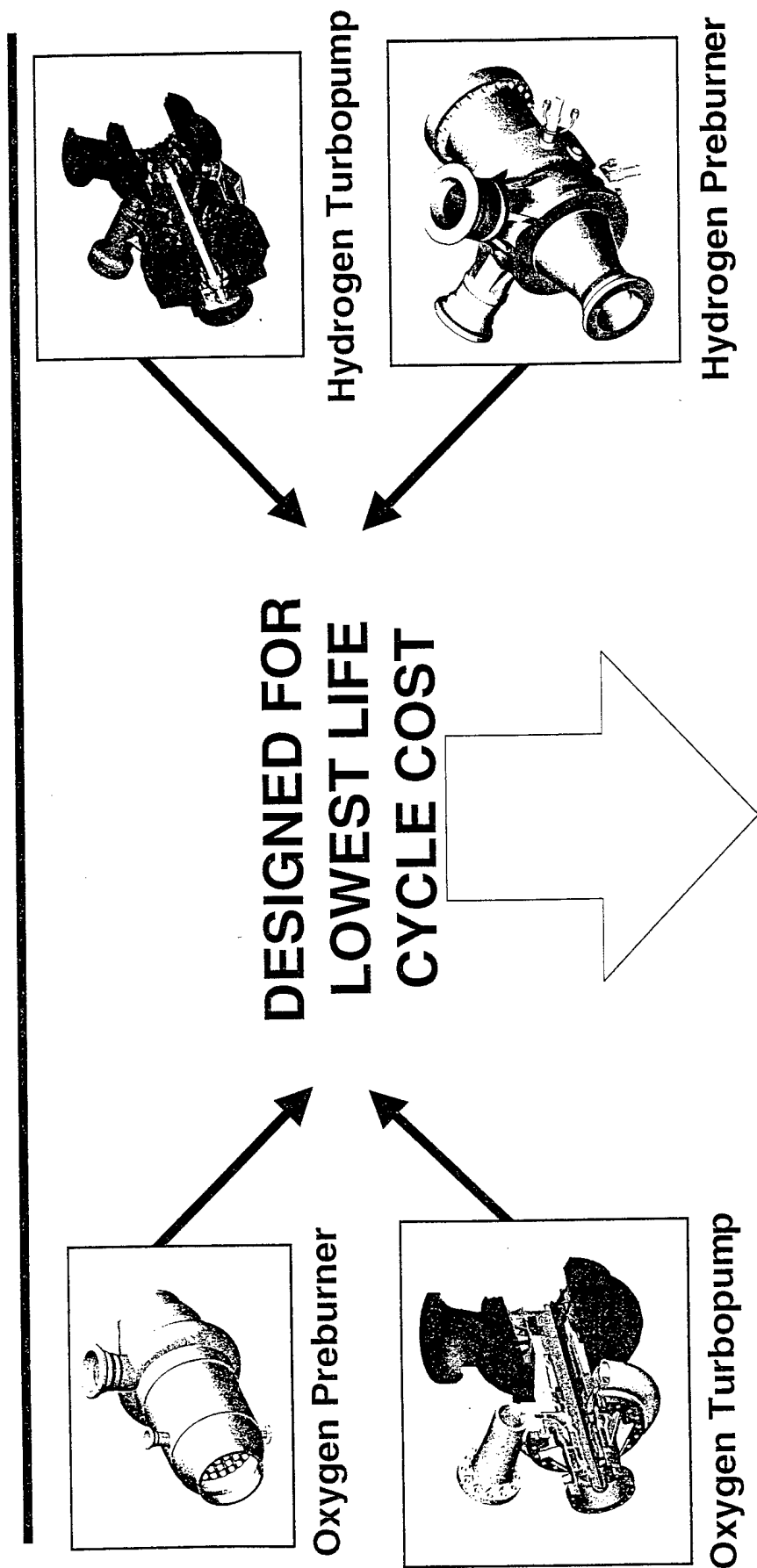
- Activation of Large Engine Test Facility at Edwards AFB
- Provides EELV With Assured Engine Test Capability
- Modern World Class Rocket Engine Test Facility
- On Track to Test Rocketdyne RS-68 for Boeing EELV



Facility System Test
9 Sep 97



Integrated Powerhead Demonstration



10X Increase in Engine Life
10X Reduction in Maintenance Cost
60% Reduction in Vehicle Size
Meets Military Spaceplane Requirements

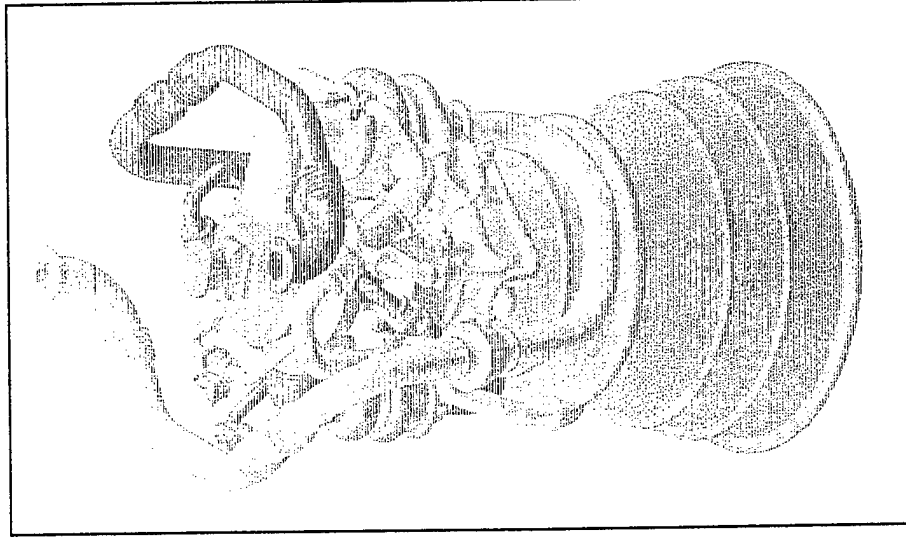


A0168.



Integrated Powerhead Demonstration

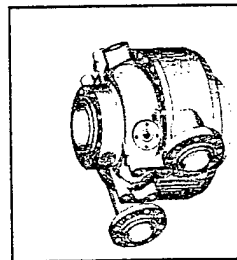
- Reusable Space Engine Technology Program
- Baseline Approach for Military Spaceplane
- Unique Design Enables 100 Missions w/o Overhaul
- Low Cost, Low Part Count, High Reliability
- Component Fabrication Underway



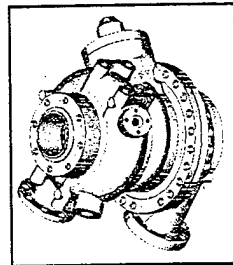
250K LO₂/LH₂ BOOSTER ENGINE



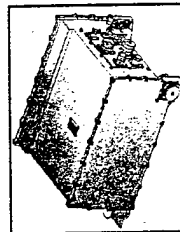
Advanced Expander Cycle Engine Demo



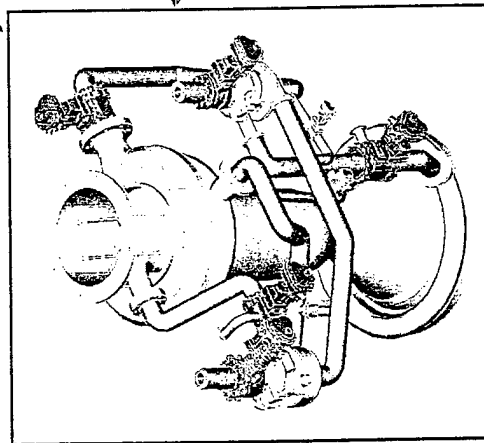
LH2
Turbopump
AFRL



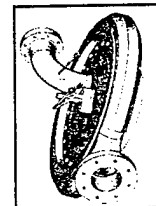
LO2
Pump
P&W



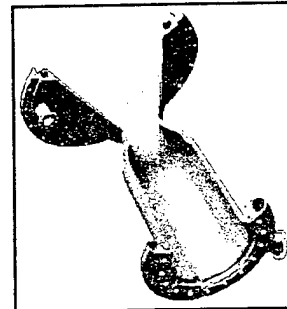
DEREC
EMA'S
AFRL



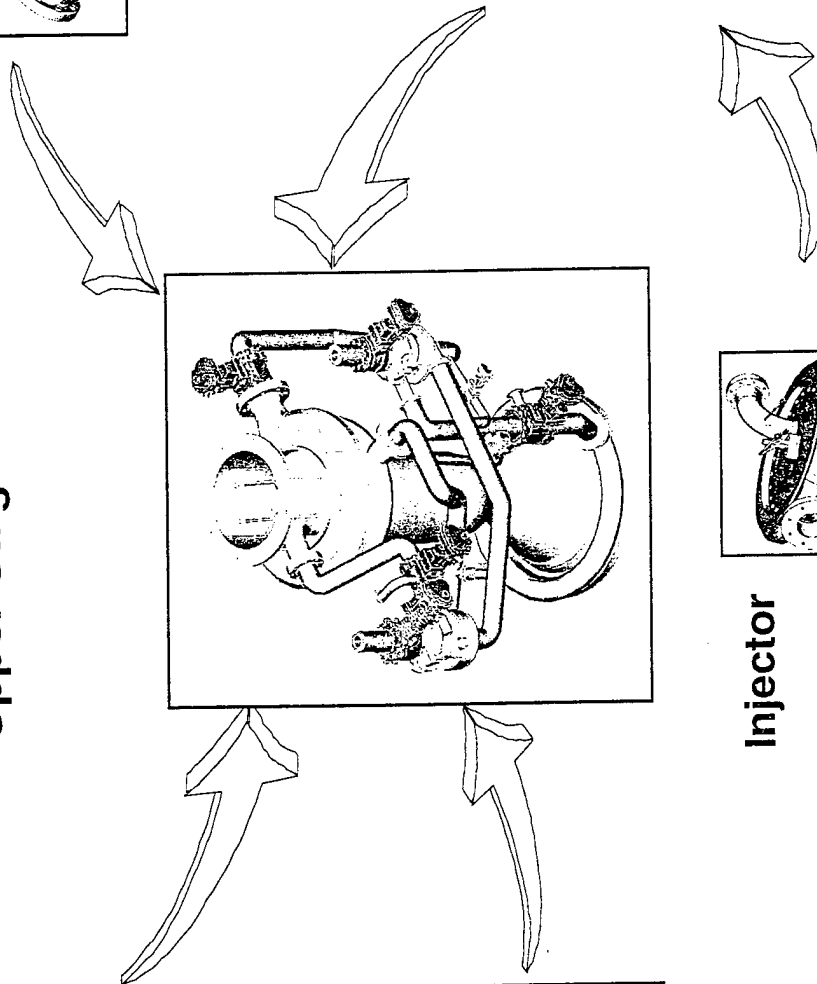
AFRL & P&W
Upper Stage Demo



Injector
P&W



AFRL
Combustor





Advanced Expander Cycle Engine IHPRPT Phase I Payoffs



- **Upper Stage**

- Increase Payload 11%-16%
- Decrease Cost 5.6%

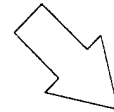
- **Other Applications**

- Booster
- Sustainer
- Military Space Plane



Future DoD/Commercial Satellite Trends

- Greater Repositioning Requirements
- Higher Specific Power
- Greater Resolution
 - Distributed Apertures
 - Large Deployables
- Orbit Insertion
- Electric Propulsion Approaches



Larger GEO Satellites

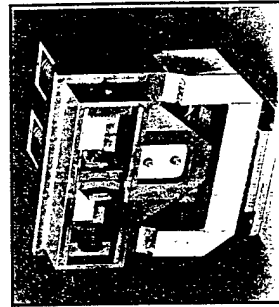
High Power Available
High Thrust Desired



Hall
Thruster

Small Sats

Low Power (<200W)
Small Impulse Bit



Pulsed
Plasma
Thruster

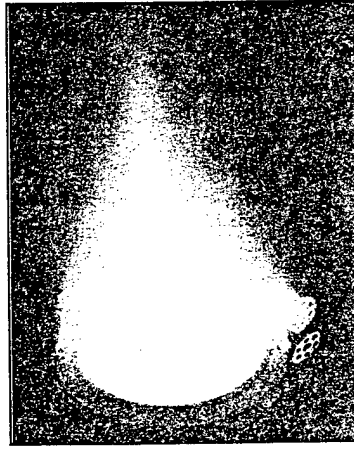


Electric Propulsion

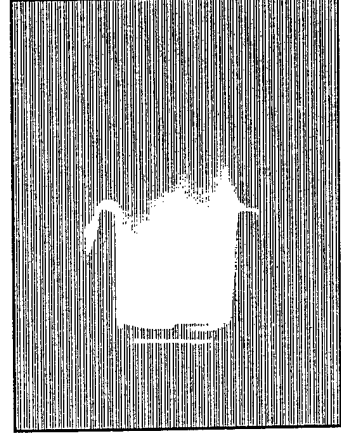


**SPACECAST 2020 - Critical Technology
for Future of the Air Force**

**New World Vistas - Enabling technology,
recommends aggressive R&D effort**



- Propulsion Directorate demonstrating Hall & Pulsed Plasma Thrusters
- Leading agency conducting fundamental research on Electric Propulsion



- Enables dramatic increases in GEO payloads
50 % near term and 300% far term increase
- Enables New Missions, Special Orbits
500% increase in Maneuvering



Solar Thermal Propulsion Critical Flight Experiment

AO168..



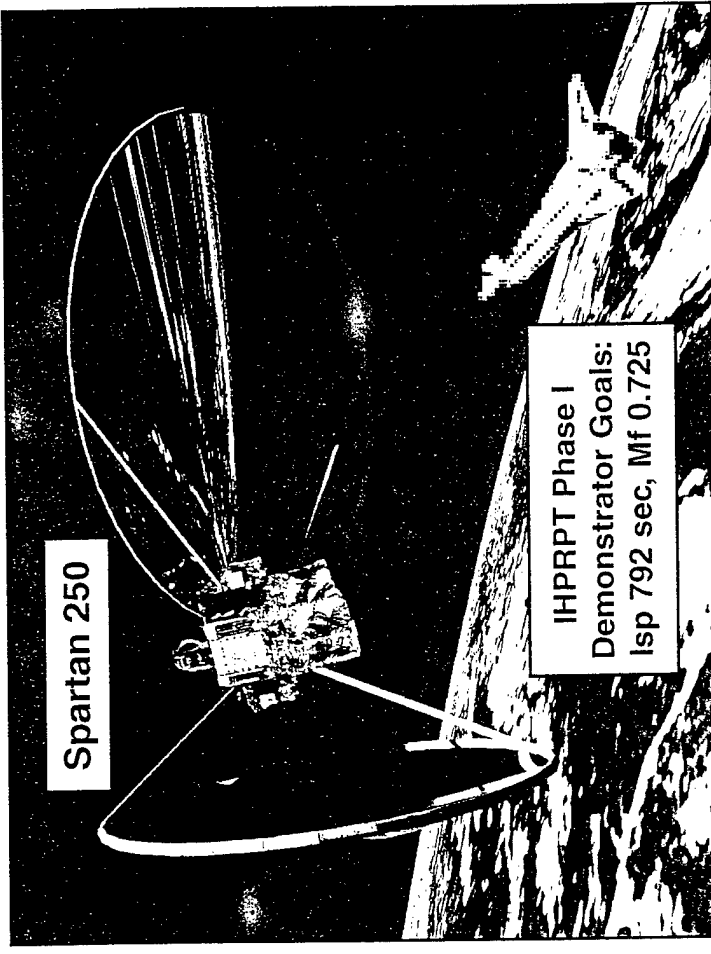
CFE Objective

- Validate inflatable concentrators
 - Deployment and pressurization
 - Optical performance 2mrad
 - Space debris, AO, UV radiation
- Demonstrate Solar Thermal Propulsion System
 - Pointing and control .1 deg
 - Integrated engine and collector
 - Plume/mirror interactions

- Meet IHPRPT Performance Goals

Secondary Inflatable Experiments

- Microwave Antenna Characterization
- PV array deployment



Flight Experiment

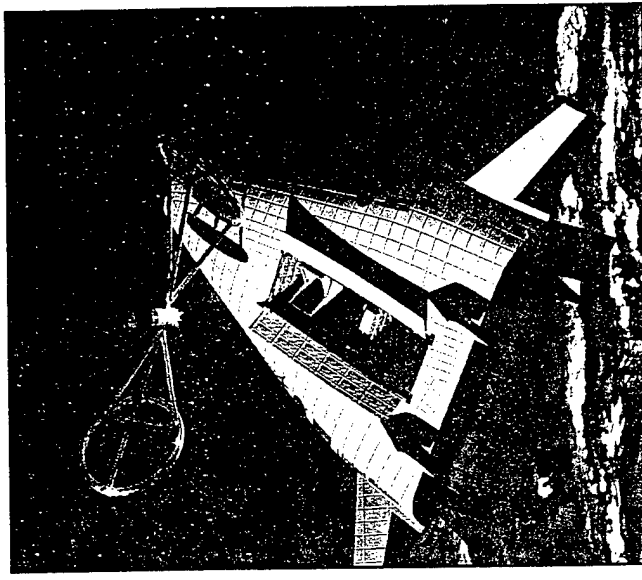
- Cooperative program with NASA
- Spartan/Shuttle launch
- Inflatable characterization
- Multiple GN2 burns
- Experiment recovered by shuttle



Solar Thermal Propulsion Critical Flight Experiment



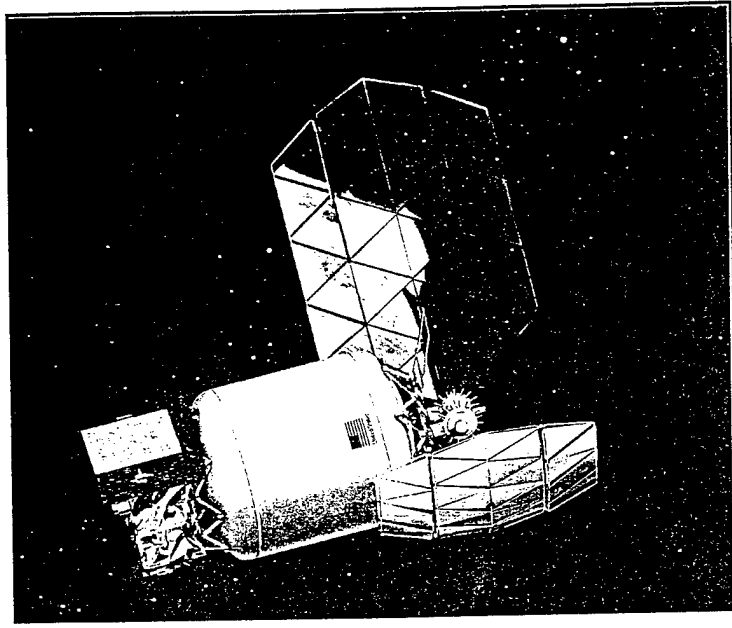
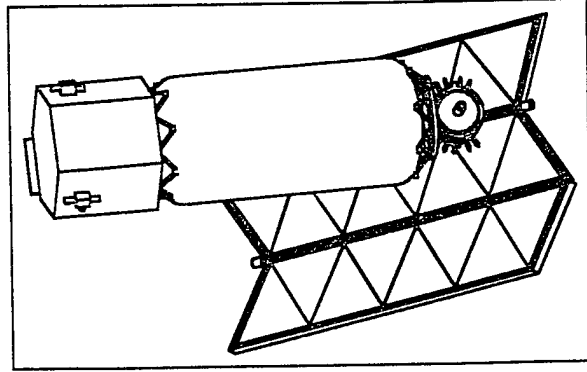
-
- Provides AFSPC with
 - Affordable Spacelift (2X payload to GEO)
 - Responsive Spacelift (Step down, <30 days)
 - Space Control (tug for repair, retrieval, denial)
 - Step toward high Isp Reusable OTV
 - Large aperture space antennas
 - Alternatives
 - EP & chemical
 - Nuclear & Laser Thermal
 - AFRL SOTV/ISUS
 - NASA Shooting Star
 - Need for Space Flight
 - Test 0g inflatable deployment dynamics and accuracy
 - Test 0g, free flight tracking and control for large inflatable structures
 - Quantify effects of LEO environment (Solar Flux, UV, AO, Debris)
 - Demonstrate solar thermal propulsion in operational space environment





AFRL SOTV

- Power and Propulsion
- Thermal storage cavity
- Single smaller rigid segmented concentrator
- Cryo H₂ storage and delivery
- Tankage interaction
- Thermionic operation
- EELV 2002 launch





Strategic Sustainment



- **USSTRATCOM Initiated Program**
 - Meets the USSTRATCOM Requirement for Sustainment of Strategic Technology
 - Funding Directed by Dr. Kaminski
 - \$67M Fenced Funding from FY98 Through FY03
- **Coordinated with the MM SPO**
 - OO-ALC/M
 - SAF/AQS
 - SMC/XRT
 - USSTRATCOM/J541
 - HQ AFSPC/DRM, DOM
- **SPO PRP Deals with Existing System**
- **Strategic Sustainment Deals with**
 - Future Technology
 - Sustainment of Propulsion Development Capability

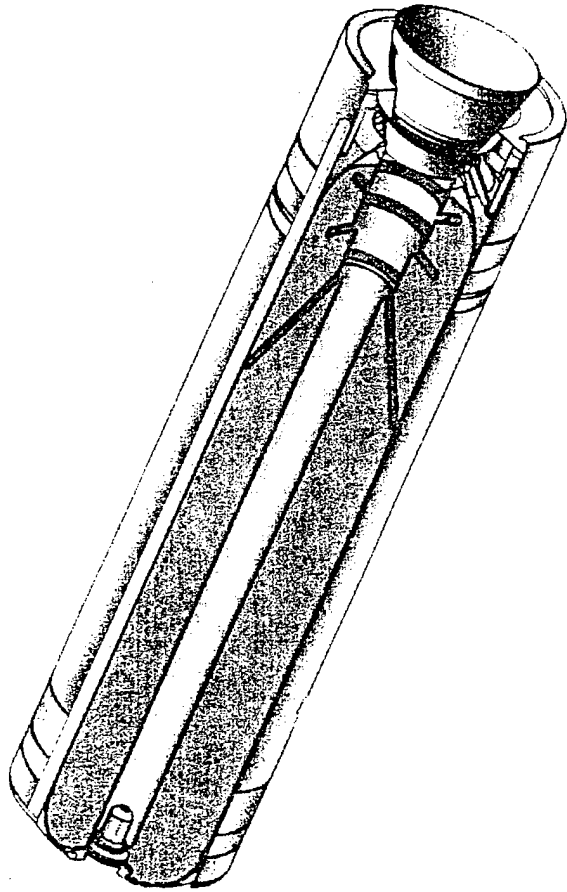


Strategic Sustainment and PRP

- Two Different Programs with Two Different Objectives
 - SS
 - Lab Program
 - PRP
 - SBICBM SPO Program
- Technology Development
 - System Maintenance (Propellant Repour)
- Sustains Motor
 - Sustains Existing System
- Development Capability
 - Component Design
 - Manufacturing
- PRP Only Does that Technology Needed to Keep Minuteman Operating



Strategic Sustainment Missile Propulsion



SUSTAINMENT MOTOR

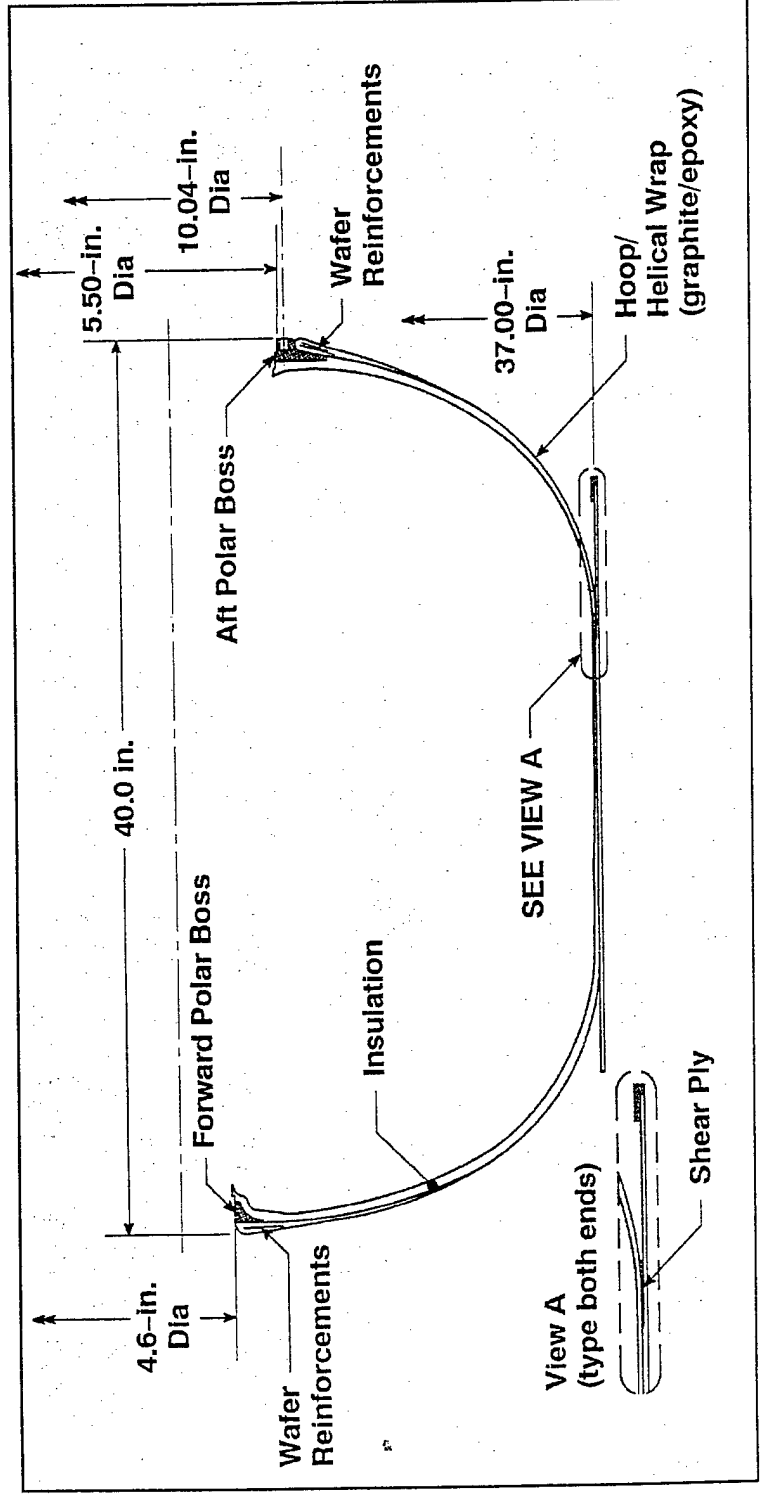
- Propellant
 - Sustainable Ingredients
 - Reduced Hazards Class 1.3
- Nozzle
 - In-Situ Densification
 - Low Cost Ingredients
- Stronger, Lower Cost Case
- Electromechanical Actuators
- Support & Hardware Cost Reduction - 25%
- Inert Weight Decrease - 15%
- Isp Increase - 4% (10 sec)



Case (Thiokol)



- Reduce Case Weight by 13.7% (Increase Castor 120 Mass Fraction 1%)
- Reduce Case Cost by 23% (Decrease Castor 120 Cost 6%)

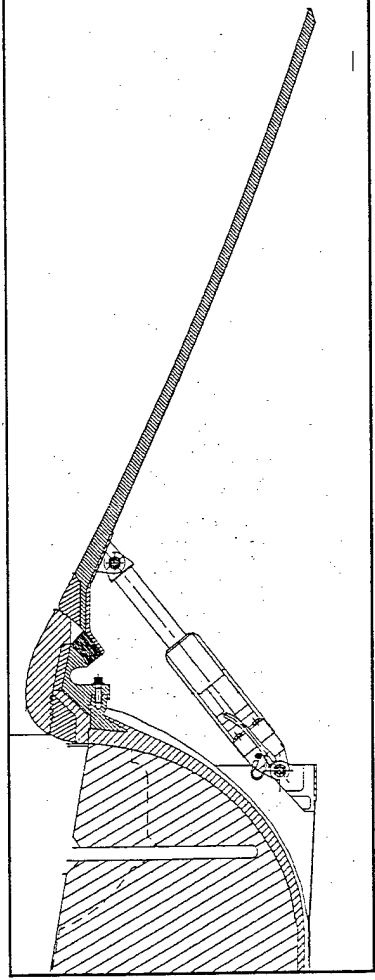




Supersonic Splitline Flexseal Nozzle



- Method to Build a Lighter and Less Complicated Nozzle
- Improves the Payload of an NMD Missiles' Second and Third Stage by 9% (even when the Length of the Missile was Constrained)
- Applied to the Orbis 1® Motor Which was used to Demonstrate the concept
 - Nozzle Weight can be Reduced by 43%
 - Nozzle Cost Can Be Reduced by 20%
 - Propellant Weight can be Increased by 1%



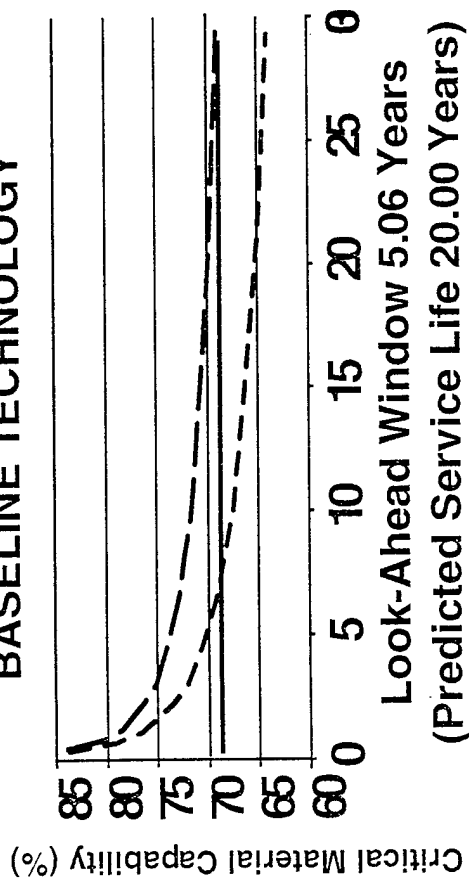
SUPERSONIC SPLITLINE FLEXSEAL APPLIED TO ORBUS-4 MOTOR



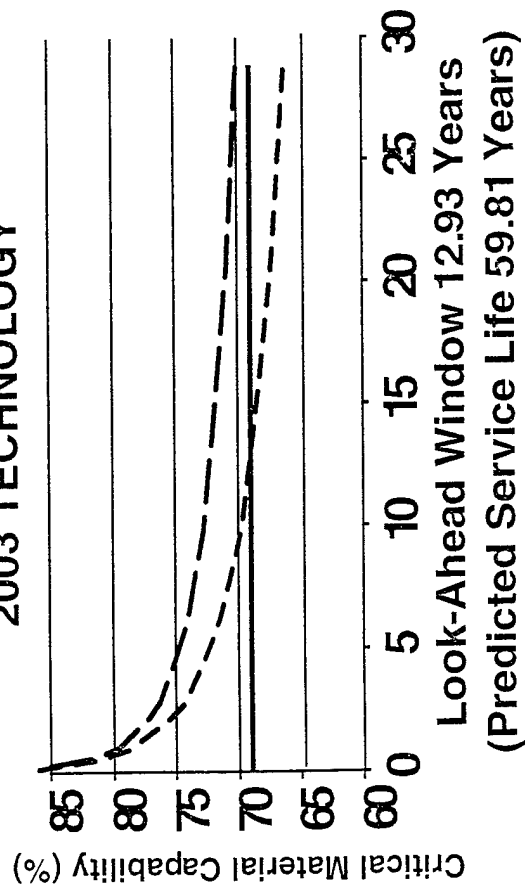
Strategic Sustainment Aging and Surveillance



BASELINE TECHNOLOGY



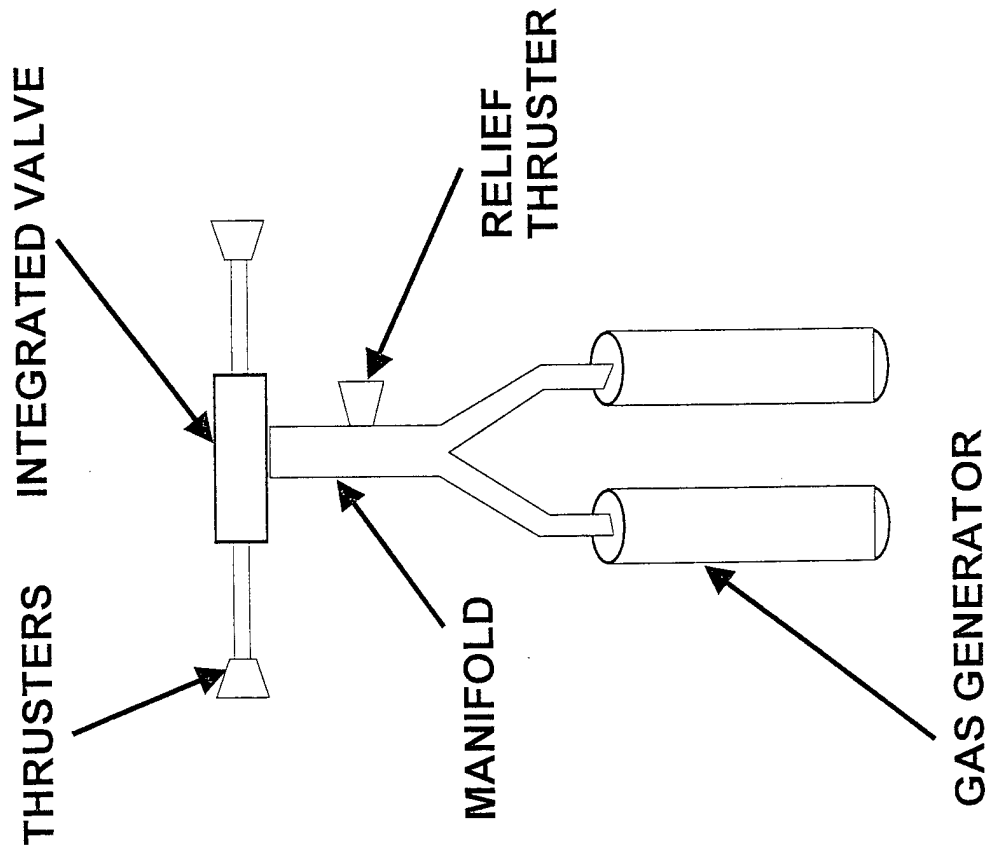
2003 TECHNOLOGY



- Address Both Analytical and Surveillance Technology
- Decrease Analysis Procedure, Aging Model & Material Characterization Uncertainties
- Extend "Look-Ahead" Window to 10 Years With 90% Confidence Level
- Develop Techniques That Permit Individual Motor Predictions
- Reduce Time and Cost for Non-Destructive Evaluation Data Processing by 50%



Strategic Sustainment Post Boost MIRV Propulsion



Solid System

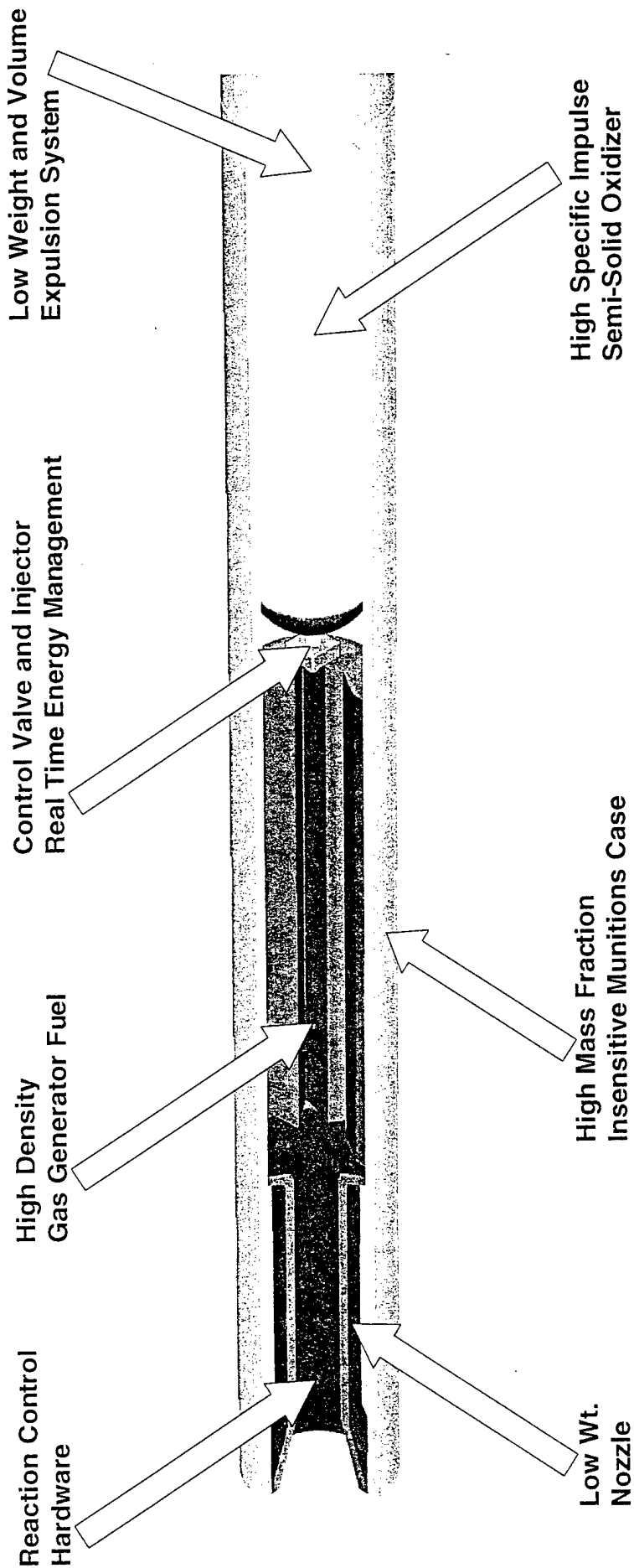
- Uses Composite Materials
 - Eliminates Unique Materials
- Uses 1.3 Propellant
 - Reduces Hazards
- Reduces Cost by 25% While Maintaining Performance

Liquid System

- Uses Non-Toxic Propellants
- Reduces Cost 35%
- Reduces Weight 50%

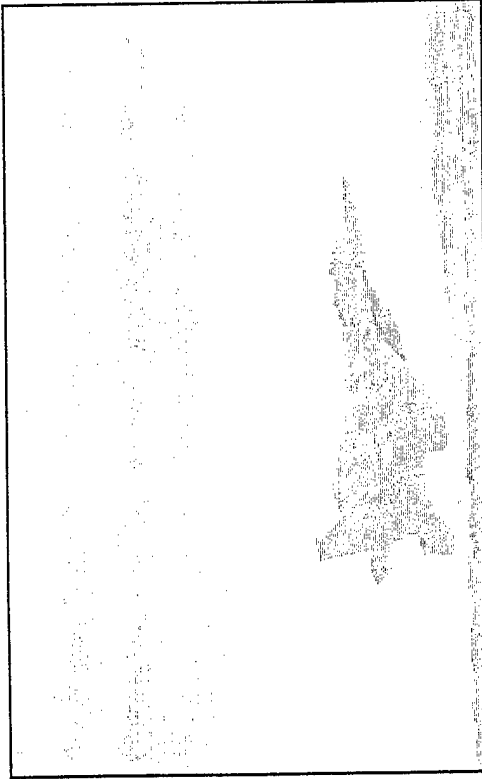


Phase II Tactical Hybrid Demonstrator Configuration





The Pay Off



- 16% Increase in Average Velocity
- 13% Increase in F-Pole
- 8% Increase in A-Pole



AFRL / PRR

6.2 & 6.3 New Project Starts

• FY99

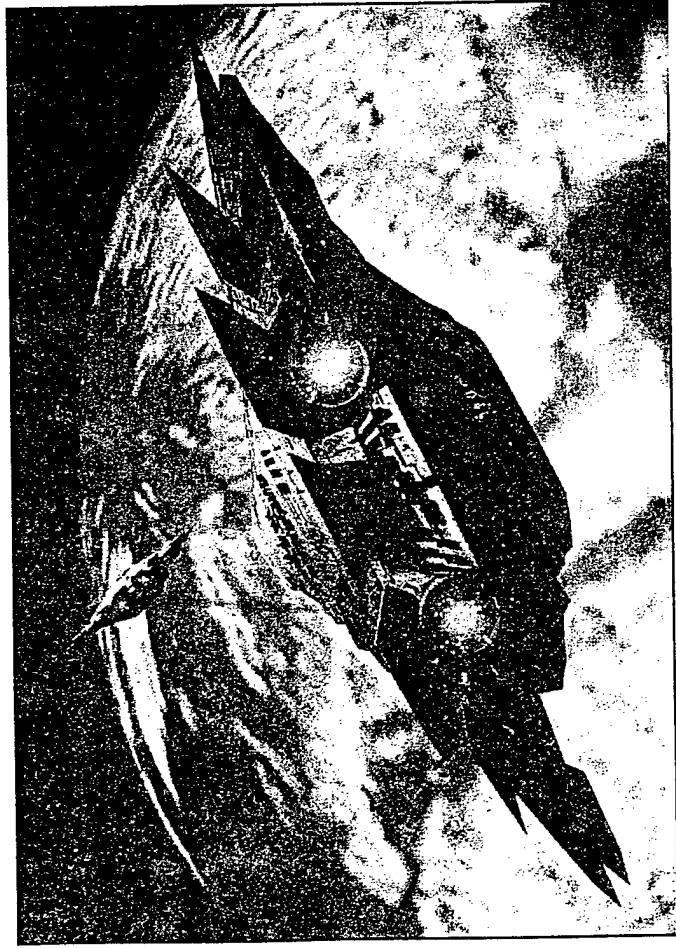
- Light Weight Engine Nozzle
- Phase I Solid Boost Demonstrator (6.3)
- Critical Defect Assessment Program

• FY00

- High Temperature Oxygen Turbine Development
- Single Stage High Discharge Pressure LH2 Turbopump
- Electric Propulsion System for Orbit Transfer (6.3)
- Strategic Sustainment Demonstration (6.3)



Propulsion Technology Enabling Future Space & Air Force Systems



- Low Cost Access to Space
- Airplane Like Operations
- Routine Space Transition Operations
- Satellite Maneuvering and Repositioning
- Missile Defense and Space Control
- New Space Based Systems
 - Space Based Radar



Conclusion

ROCKET PROPULSION DIVISION

- GUARANTEED to support the warfighter
 - Close bond between PL and AFSPC
- Honest Broker / Expert Consultant
- One Place gives Full Spectrum Capability (Unique Facilities)
- A Center of Excellence for Propulsion
- Innovative Research
- Corporate Responsibilities

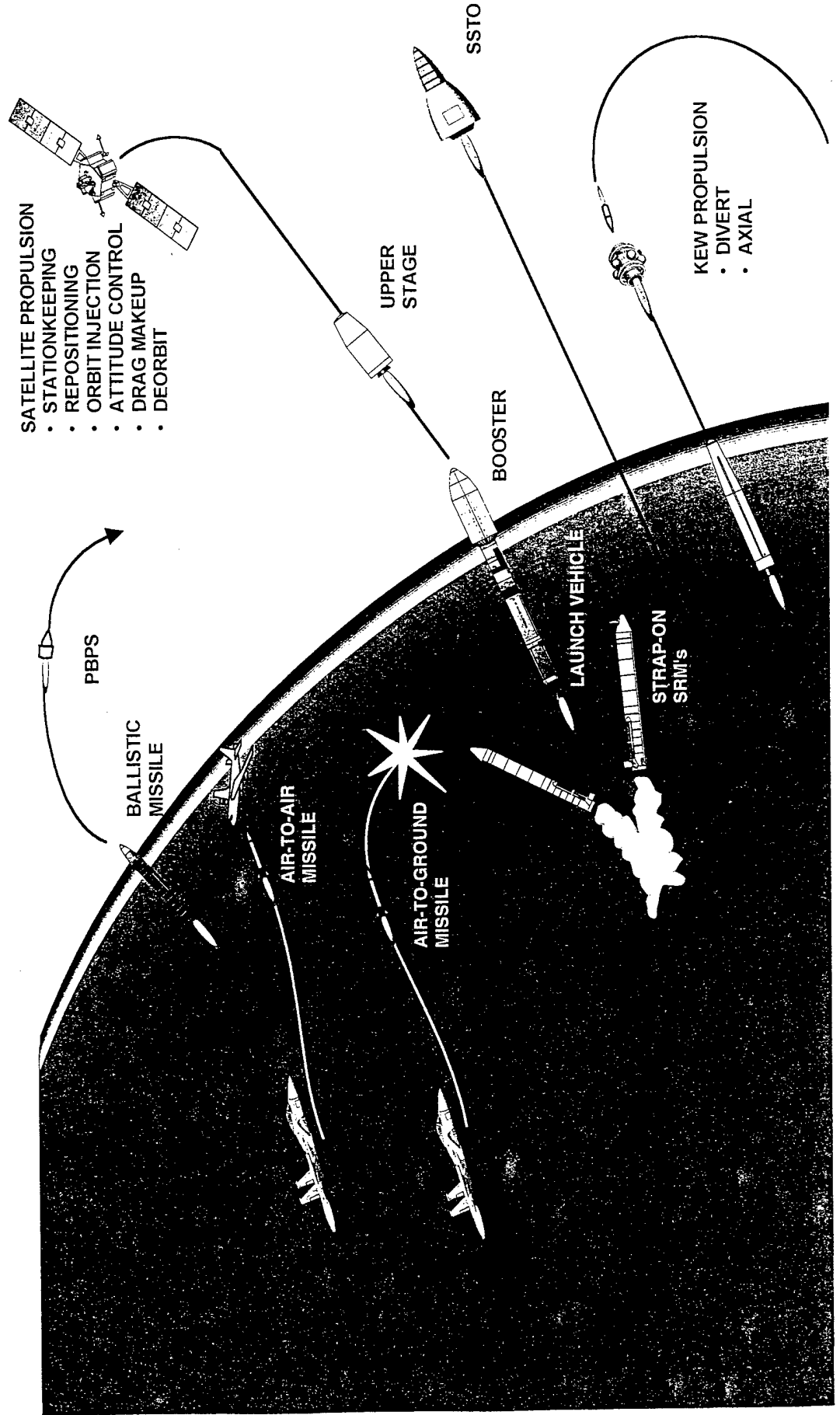
THE MAJOR NATIONAL LOCATION

FOR ROCKET PROPULSION

TECHNOLOGY



Rocket Propulsion Technology Fundamental to all Space & Missile Systems





Tactical Propulsion Minimum Smoke Propellant Development

AO168..



Objective

- Demonstrate Next Generation of Low Hazards, High Performance, Low Signature Propellants

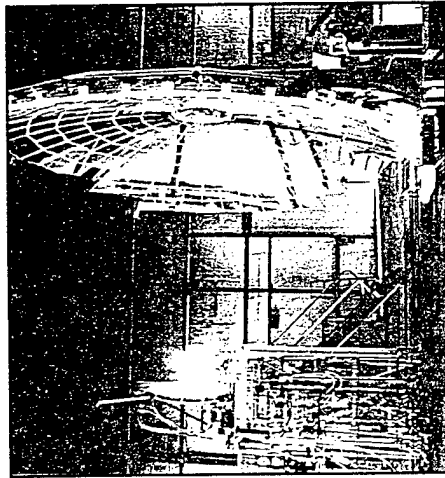
Approach

- Air Senior National Representative (ASNR) Sponsored Effort
 - France: Ballistics & Hazards
 - Germany: Formulation Characterization & Performance Calculations
 - United Kingdom: Mechanical Properties & Aging
 - U.S.: Formulation Characterization, Ingredient Analysis & Performance Calculations



Solar Propulsion Laboratory

World Class Facilities



- ONLY U.S. SOLAR FACILITY USING LH2
- 10000:1 CONCENTRATION RATIO
- 3400K GAS TEMPERATURE



- 30 FOOT DIAMETER VACUUM SPHERE
- ONLY LARGE U.S. VACUUM FACILITY RATED FOR 100,000 LBS LH2

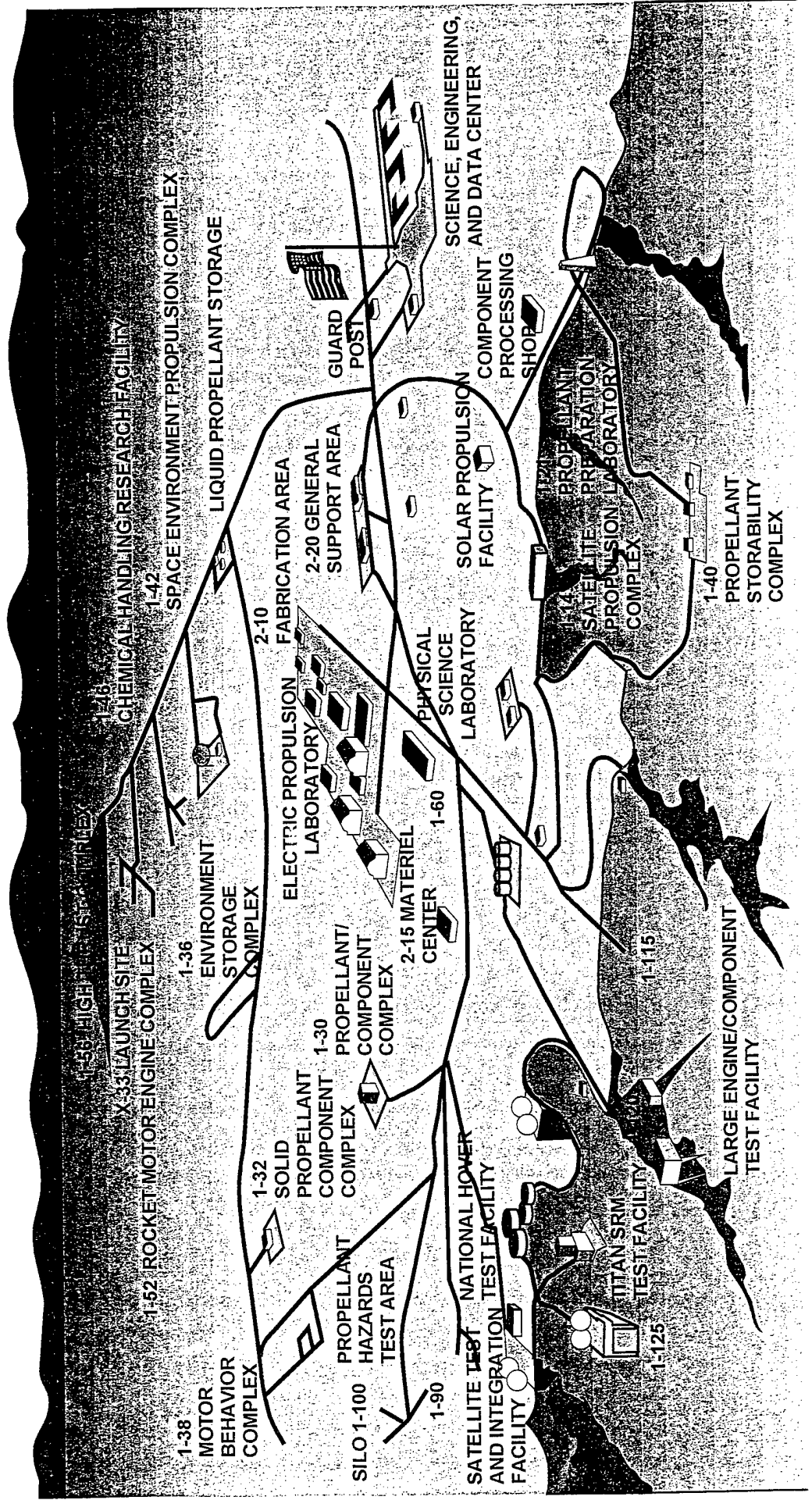
Center of Excellence for U.S. Solar Efforts

- Laser Power Beaming (PL/LI)
- Solar Bimodal Propulsion and Power (PL/VT)
- Industry / AF / NASA / University Solar Consortium CRDA
- Hercules CRDA
- Commercial Spin-Offs
 - High Temperature CC Springs
 - Holographic Embossed Thin Films for Medical CATscans
 - Compressed Natural Gas Bladders for Chrysler Corp.
 - Polyimide Concentrators for Space Based RF Antennas



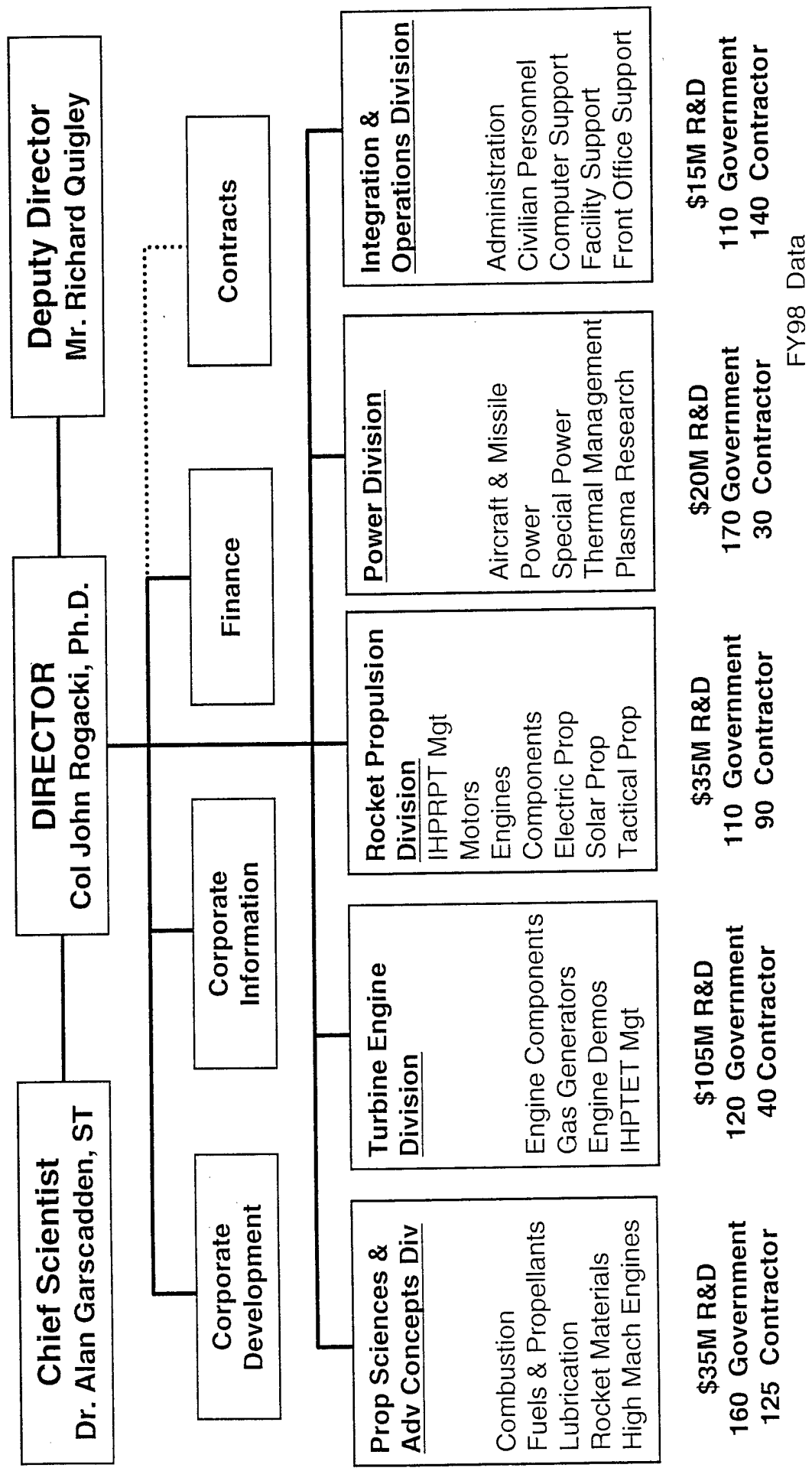
Propulsion Directorate

Rocket Propulsion Facilities



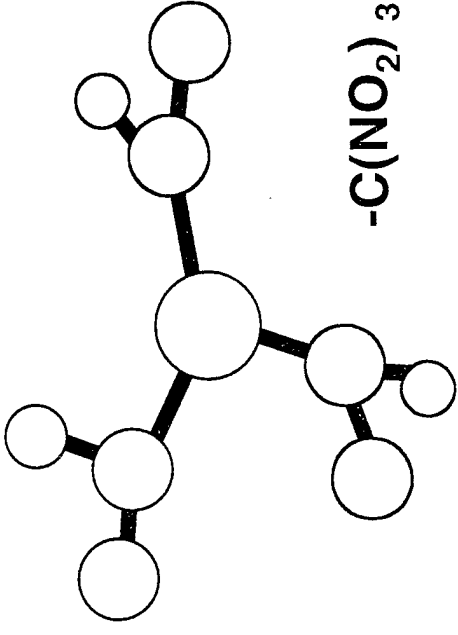


AFRL Propulsion Directorate





New Energetic Monopropellants



Payoff

- Double Satellite On-Orbit Lifetime
- Non-Toxic Replacement of Hydrazine
- Candidate for Military Space Plane

Approach

- Low melting salts, dissolved in solvents
- Low volatility, low toxic

Status

- Several candidates synthesized
- Low shock sensitivity, low cost

Candidate Propellants Isp (sec)* p (g/cc)

• Hydrazine	198	1.00
• Peroxide	164	1.43
• XM46 (HAN/TEAN)	244	1.43
• RKS-M1	270	1.69

* Pc=1 --- psi, Sea Level exhaust